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PROJECT 205A

PROPOSAL FOR RESTRAINED COLUMN TESTS

by T. V. Galambos & M. G. Lay

1. INTRODUCTION

Experimental results at Lehigh¹ and elsewhere² have produced a large number of test results for compression members with and without applied end-moments. These results have led to a better understanding of the experimental and theoretical behavior of individual beam-columns and to an improvement in the methods of designing them. However, the isolated beam-column in the testing machine is not fully representative of a compression member in a real structure. In a structure the moments on a column are related to the rotations at the ends of the member and are thus dependent on the properties and characteristics of the rest of the structure.

For many years the design of structures containing compression members had been retarded by a lack of simple methods for predicting the end-moment end-rotation relationships for axially loaded members. However, recent work at Lehigh³ has removed this obstacle by providing theoretically calculated column deflection curves. These curves appear to

1 Numerals refer to references on Page 10.

be soundly based theoretically* and have checked with a limited number of experimental results⁴.

The main usefulness of this restrained column theory³ is that it allows the moments and rotations in a beam-column to be related to those in the rest of the structure and methods of analysis based on this approach have since been published⁵. These new methods are an important analytical advance and, in addition, have opened the way for the application of plastic design methods to structures in which instability effects are important⁶.

As in simple plastic design, failure is defined as the attainment of the maximum load which the structure as a whole can support, and not as the load corresponding to the maximum strength of some individual member. A consequence of this more logical definition is that it is possible to utilize more of the reserve of strength of the structure.

2. PURPOSE OF THE TESTS

The tests to be discussed in this proposal are primarily aimed at checking the theoretical basis for the methods of analysis developed in References 5 and 6. Four

*It is noted that the curves apply only to in-plane behavior in the absence of local buckling.

main facets require investigation at this stage of development:-

(1) Do the column deflection curves correctly represent the shape of a beam-column which is part of a real structure?

(2) When calculating the failure load of a structure is it sufficient to ensure that the various joint rotations are compatible?

(3) Are the methods of calculation sufficiently refined to yield accurate results?

(4) Is the classical criterion for instability⁷ a valid one to apply to a real structure?

3. ARRANGEMENT OF TESTS

i) Set-Up

Whereas past tests¹ have concentrated on individual beam-columns, the proposed tests will use subassemblages in which one member is a beam-column. Figure 1 shows a diagrammatic arrangement of the proposed set-up. AB is a beam-column and it is loaded by end moments applied through stub-beams AE and FB and by axial loads through A and B. Joints A and B are also restrained by restraining beams CA

and DB which are both unloaded along their length.

The loading system is designed to place the column into single curvature deformation. This mode is the most critical from an instability aspect and as the tests will be confined to the smaller, more practical slenderness ratios (see section 3 (ii)) it is necessary to select the most severe failure mode in order to obtain well defined experimental results.

ii) Types of Tests

The tests are designed in two groups and three divisions (see Table I). The first group contains shorter, more highly loaded columns, while the second group contains longer columns which are not so highly loaded, and thus the two groups represent the two major column types.

The three divisions are such that in the first the beams remain elastic, in the second some yielding occurs, and in the third the beams form plastic hinges. Thus the design spectrum from weak column-strong beam to strong column-weak beam is represented. In these tests it is to be noted that the initial signs of failure will not necessarily be in the columns, however, final collapse of the subassemblage

will include both beams and columns.

Eight tests are proposed to check out the various aspects of the theory. Six of the tests fall directly into the groups and divisions outlined above and two overlapping tests are planned to examine the effect of variations in the lateral bracing. Table II details the eight tests and the sections and dimensions which will be used.

If the assumptions discussed earlier are found to be justified, then these tests will be sufficient, otherwise it may be necessary to propose further tests at a later date.

iii) Sections and Dimensions

The column deflection curves were derived specifically for the 8WF31 and it is thought desirable to use this for the test columns and thus eliminate one variable from the results. Having chosen the column section the beam sections available are restricted. For a given set of conditions the critical beam variable is its length/depth ratio and, to eliminate another variable, the beam section is kept constant and its length is varied (Table II).

Instability is not a serious problem for most structures in which the column axial load is less than

$0.15A\sigma_y^*$ and thus it is necessary that the tests duplicate real structural conditions with higher axial load values. Such conditions frequently exist in the lower stories of multi-storied frames and in other cases where the beams are small relative to the columns. To produce these instability conditions, the beam section shown in Table II will be used. These member sizes are thus probably smaller than would be encountered in a similar practical situation, however, the use of larger sizes would make the set-up inconveniently large.** The actual beam section chosen is a column type as the larger value of r_y reduces the bracing requirements.

iv) Details

Further details of the testing arrangement are shown in Figures 2a and 2b. Bearings are used to support the joints for two main reasons:

(1) To fully investigate the mode of failure it is necessary to ensure that considerable end rotation can take place. The spherical seats and knife edges used in previous tests at Fritz Laboratory do not provide sufficient rotation capacity.

(2) It is important that the applied load introduces no unknown moments at the joint. As there are three members

* A is column area, and σ_y the material yield stress.

**From Fig. 1 and Table II it is seen that the proposed test arrangement will be about 20' high.

meeting at a joint it is not possible to do this with simple knife edges. A spherical seating could be used but would not provide sufficient restraint against lateral movements.

The bearings must have low frictional properties under very high pressures and the problem of a suitable bearing has been investigated. At this stage it would appear that either a heavy duty roller bearing, a self-lubricating bearing or a bearing using high pressure lubricant would be satisfactory.

The testing will be done in the 5,000 kip machine and the moments will be applied and measured by jacks and dynamometers available in the laboratory. Other end fittings and bracing fixtures are also available¹.

Rotations of the joints will be recorded and also the deflected shapes of all members. The tests will not be extensively strain gaged.

4. FORM OF EXPECTED RESULTS

Figure 3 shows the expected results for the six tests RC-1 to RC-6. The column curve is for the complete column loading path while the beam curve is only for the situation at failure.* It is seen that the six tests cover the full range of theoretical possibility. Tests RC-1 to RC-3

* The process of combining the beam and column curves is described in reference 5.

demonstrate failure near the peak of the column curve with test RC-3 being the extreme case of a plastic hinge forming in the beam before overall collapse. These tests will provide a good indication of the effectiveness of the design procedures.

Tests RC-4 to RC-6 in Figure 3 illustrate the same points but with greater emphasis on checking the adequacy of the collapse criterion (the point of tangency of the two curves). Test RC-6 is very nearly the hinged beam case. However, in RC-4 and RC-5, collapse should occur well after the peak of the column curve has been passed. Thus these tests will provide a most effective check of the collapse criterion and of the unloading portions of the column deflection curves.

These six tests will indicate whether the curves shown in Fig. 3 can be reproduced experimentally. If discrepancies arise, the range of the tests will allow the cause of the error to be determined.

RC-7 and RC-8 will be used to discover whether the absence of lateral bracing will invalidate the theories and whether simple steps can be taken to overcome the lateral

bracing problem. Previous results⁴ would indicate that lateral buckling may seriously affect the application of the theory. No theoretical results are as yet available to this problem so expected results can not be presented.

In RC-8 the center of the column will be boxed with light gauge metal to improve its torsional stiffness.

5. FINANCES

The cost of these experiments has been included in the regular 1962-1963 budget for the "Restrained Column" project and therefore this proposal does not include a request for additional funds.

6. CONCLUSION

The tests will constitute an important advance in experimental structural knowledge,* and it is essential that design methods⁵ at present being proposed and accepted be placed on a sound experimental basis. In addition the tests will serve as useful pilot tests for the investigations of larger subassemblages which must soon eventuate.

* From Fig. 1 it may appear that the tests resemble some of a series performed at Cambridge University² after the last war. However, these were tests of columns only and the purpose of the beams was to transfer load to the columns. The beams were extremely rigid relative to the columns and only the columns were under any distress at failure. The columns were in various curvature modes and not many single curvature columns were tested. So the Cambridge tests resemble the Lehigh beam-column tests¹ or an extreme, limiting case of the tests contained in this proposal.

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			DIVISIONS		
			→ BEAM STIFFNESS INCREASING →		
			FLEXIBLE BEAM		STIFF BEAM
			L/d = 38.4	L/d = 28.2	L/d = 19.2
GROUPS	COLUMNS LONGER	$L/r_x = 60$	RC-1	RC-2,7,8,*	RC-3
	LOAD LOWER	$P/P_y = 0.40$			
	COLUMNS SHORTER	$L/r_x = 40$	RC-4	RC-5	RC-6
	LOAD HIGHER	$P/P_y = 0.60$			

* RC-7,8 are tests to investigate bracing effects.

RC-7 No column bracing.

RC-8 No column bracing, column boxed at mid height.

TABLE I
TYPES OF TESTS

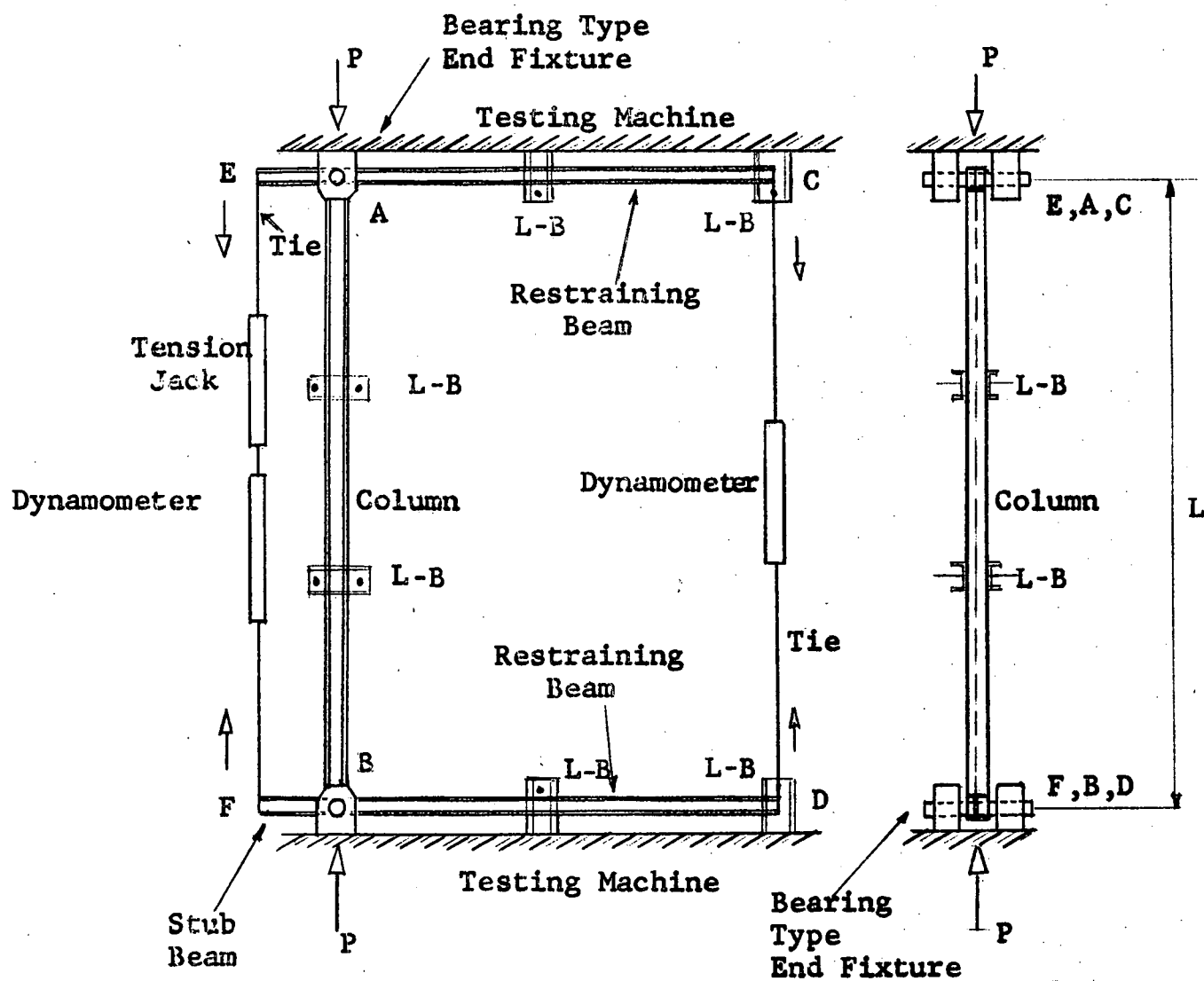
TEST	COLUMN			RESTRAINING BEAM*	
	AXIAL LOAD (KIPS)	SECTION	LENGTH** (INS)	SECTION	LENGTH** (INS)
RC-1	120	8WF31	208	5WF18.5	192
RC-2	120	8WF31	208	5WF18.5	144
RC-3	120	8WF31	208	5WF18.5	96
RC-4	180	8WF31	139	5WF18.5	192
RC-5	180	8WF31	139	5WF18.5	144
RC-6	180	8WF31	139	5WF18.5	96
RC-7	120	8WF31	208	5WF18.5	144
RC-8	120	8WF31	208	5WF18.5	144

* The stub beam is always an 8WF40, 32" in length.

** Lengths are center to center.

TABLE II

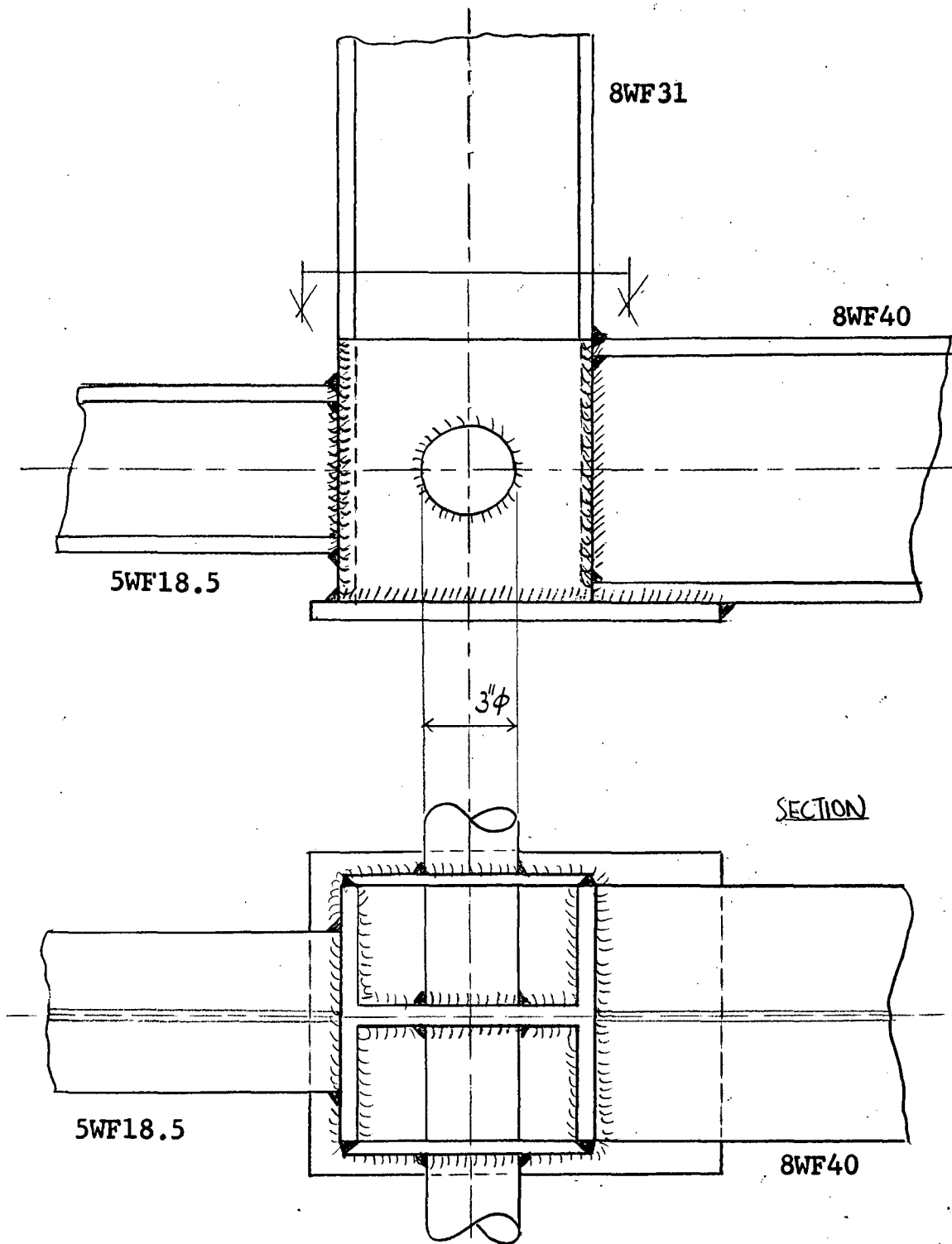
MEMBER DIMENSIONS AND SIZES



L-B - Lateral Bracing Fixtures

FIG. 1.

DIAGRAMMATIC ARRANGEMENT OF PROPOSED TESTS

FIG. 2AJOINT DETAIL

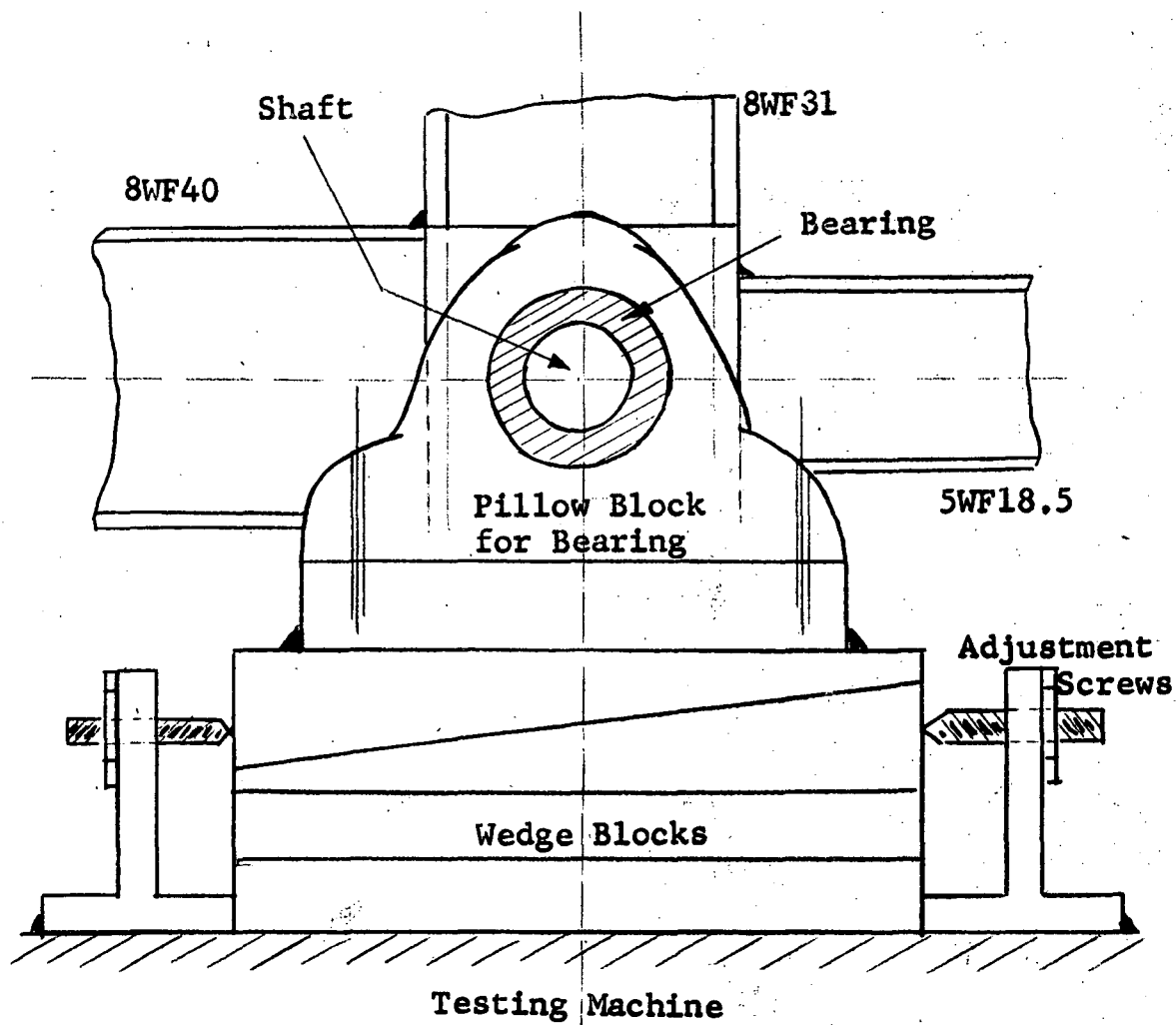
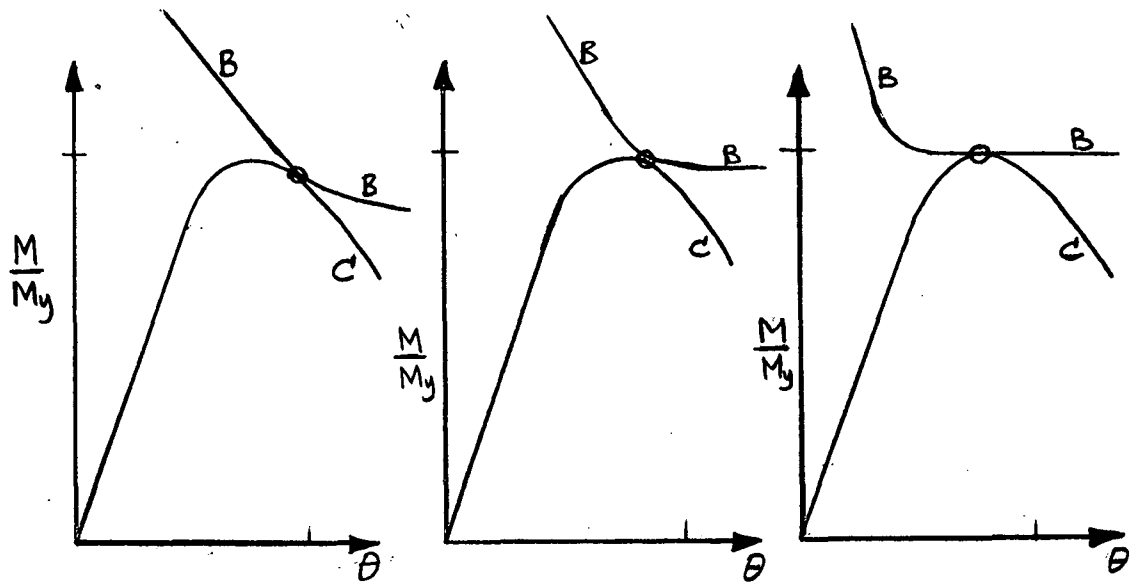
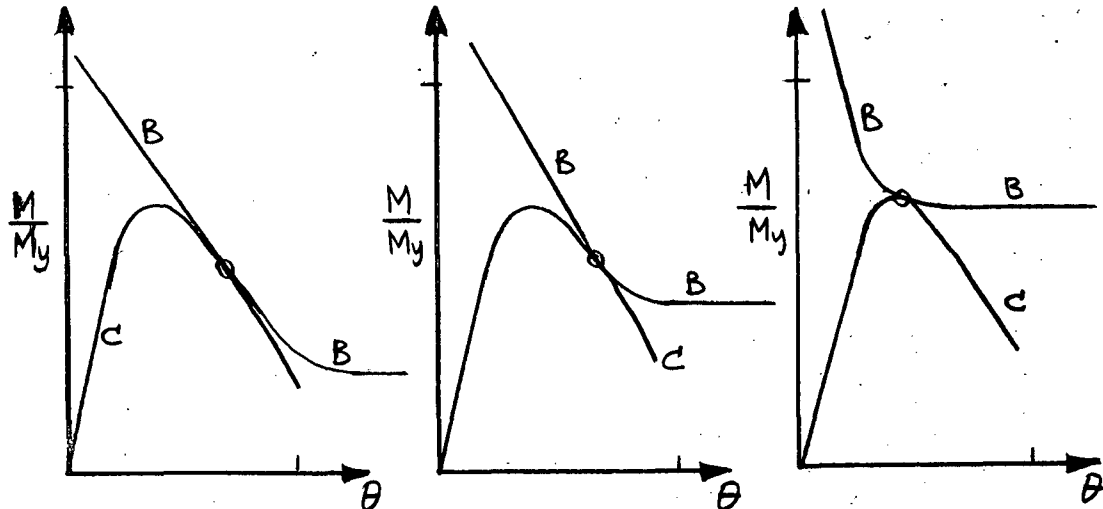


FIG. 2B

BEARING DETAIL

Test RC-1Test RC-2Test RC-3Test RC-4Test RC-5Test RC-6

B - Beam Curves, M - Applied Moments
 C - Column Curves, theta - Joint Rotations

FIG. 3

PREDICTED RESULTS FOR TESTS RC-1 TO RC-6